controlled mosaics. As the preparation of the map is undertaken, field sheets are copied and reproduced; manuscript maps are reproduced on metal-mounted papers and glass; prints of the various color separation plates are reproduced for lettering layouts and editing work; black-and-white composites are made for area determination and editing; and color proofs are used for final checking.

Lithographic reproduction of the completed soil map is done by commercial lithographers under contract. The Division of Soil Survey prepares the lithographic specifications, makes the necessary cost estimates, and inspects and checks the work prior to acceptance.

During the process of lithography, proofs are submitted for inspection. The first color proof shows only the line work, culture, drainage, soil boundaries, soil symbols, and lettering. The second proof shows the color tints for the soil grouping. Each proof is thoroughly checked for quality, registration, and color, and the contractor advised of the corrections to be made. The final lithographic run is inspected and approved for acceptance if it meets the specifications.

GEOGRAPHICAL AIR-PHOTO-INTERPRETATION*

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AIR-PHOTO-INTERPRETATION is relatively new in geography. Evidences of this youthfulness are the scarcity of articles by geographers on the technique,[1] the recency of development and relatively low number of formal courses on interpretational uses of air photos, and the paucity of known geographical research involving developments in the technique.

Such a situation is paradoxical. Geographical specialization naturally leads to intensive use of air photos. Generally, too, a well-balanced geographical training program has proved to be one of the better bases of high efficiency of interpretation. Direct relationships are to be expected because the geographical discipline is based upon analyses of distributional patterns, occurring together intricately or simply, throughout the world.

If the map is a major tool of the geographer, so is the air photo. The differences between the two are generally in scale, the number of distributional patterns portrayed, and the apparent complexity of relationships between these patterns. In many ways an air-photo is simply a small-sized but large-scale map not made on any true projection, and without symbolization or selectivity of features in the area covered. We might be better advised to think of the photos as *areal* instead of aerial.

Yet there is confusion about air-photos, among geographers and non-geographers alike. The perplexities concern the availability of photographic coverage, the relative cost of the pictures and interpretational equipment, security regulations regarding developed photo-interpretational recognition

* Research upon which portions of this paper are based was aided by the University of Wisconsin.

[1] U. S. Naval Photographic Interpretation Center, Abridged Bibliography of Photographic Interpretation, Report No. 102A/50, Washington, D. C., November 1950; Forest Service, U. S. Department of Agriculture, The Use of Aerial Photographs in Forest Surveys (Allegheny Forest Experiment Station), Philadelphia, Pa., 1 June 1944; G. C. Cobb, Bibliography on the Interpretation of Aerial Photographs . . . , *Bulletin of the Geological Society of America*, v. 54, August 1943, pp. 1195–1210. See also the interpretational references noted in American Society of Photogrammetry, Committee on Bibliography, Bibliography of Photogrammetry . . . , PHOTOGRAMMETRIC ENGINEERING, v. 2, Oct.–Dec., 1936, complete issue.

keys, the multiple uses of air-photos, and the absence of standardization of interpretational procedures. A large part of the world already is covered by one or more sets of air-photos;[2] these may be purchased at a relatively (to field work without the photos) low cost[3] and analyzed with a portable stereoscope[4] and acetate photo-interpreter's scale.[5] Non-military personnel, at first, will have to interpret in the absence of classified developments in interpretation. However, this is not as serious a penalty as might appear because many of the new keys have mostly military value; further, there is an encouraging trend on the part of military agencies in the world to release more data on applications of the technique.

Thus, the significant topics about the use of air-photos are two in number: 1) Recognition of the multiple uses of a photograph narrows the field of a potential interpreter; 2) The establishment of procedure prepares the way for orderly and complete analyses of complex subjects. Further progress then, as in any technique, depends upon the additional experience and imagination of an interpreter.

Three Fundamental Uses of Air-Photos

Each air-photo may be used in three distinct ways: 1) for photo interpretation, 2) for photogrammetry, 3) and as a base for mapping. Such uses are complementary. However, proficiency in each is a separate field of specialization.

1) Air-photo-interpretation is a research technique. It requires vision with the naked eye and a stereoscope combined with available source materials. The purpose is to recognize on air-photos and determine the significance of selected natural and cultural features. Inasmuch as the technique includes analyses of all types of elements of the landscape throughout the world, it would appear that one person may be occupied sufficiently as an interpreter alone. This situation is so true that general, rather than topical or regional, photo-interpreters may be expected to be rare. Also, geographers and other scientists aspiring to efficiency in photo-interpretation must guard against discouragement in the preliminary stages of learning. At the same time, they must recognize that photogrammetry is a different field of activity.

2) Photogrammetry is a topographic specialty in engineering. It generally requires the availability of and ability to operate relatively complex equipment with a high degree of accuracy. The purpose is to prepare maps with a degree of accuracy equal to or superior to what might be done by surveying in the field.

Differences between the work of photogrammetrists and interpreters are legion. Interpretation, for example, is generally done on much smaller scales

[2] Specific current data on United States coverage are available on maps from The Map Information Office, U. S. Geological Survey, Department of the Interior, Washington 25, D. C. Information about photographs taken by Department of Defense agencies of foreign areas may be procured from: Headquarters, U. S. Air Force, AC/AS-2, Photographic Records and Services Division, Washington 25, D. C. or from the Chief of Naval Operations, U. S. Department of the Navy, Division of Public Relations, Washington 25, D. C. Additional knowledge about foreign coverage is usually obtainable from the official representatives of foreign governments in Washington, D. C.

[3] An average cost of .50–$1.00 per print prevails for orders of a few photos from domestic and foreign, private or governmental agencies. For orders of 100 or more prints the cost of each picture may be as low as .35–.75 cents.

[4] The analysis may be made with two small reading lenses spaced about like glasses and supported about 4½ inches above the photos. Manufactured items are procurable from several firms, all of which advertise in PHOTOGRAMMETRIC ENGINEERING.

[5] A six-inch transparent scale graduated to thousandths of a foot and manufactured by The Photoplating Company, 215–217 N. E. Fifth Street, Minneapolis 13, Minnesota.

than photogrammetry when air-photography of various scales is available for the same area. Also, an interpreter generally is more concerned with the specifics of land use or land types, while the photogrammetrist's major interests usually are the details of the site factors and construction. These differences are merely products of dissimilar objectives in the use of air-photos. There is need for both objectives. However, photo-interpretation and photogrammetry have become too well developed for most individuals to master each field. Rather, we seek cooperation between two specialists.

3) The use of a photo as a mapping base is limited to no one discipline. Special equipment is not essential. Many scientists, particularly geographers, recognized years ago the superior value of a 1/20,000 air-photo over a blank piece of paper on a plane table. Orientation was simpler, transportational and field lines were shown, and scale relationships in location were established. Techniques of mapping on the photos, such as pricking and grease penciling, were devised. This use of air-photos fostered the rapid development of the other two uses, particularly interpretation, and hastened the necessity of the development of interpretational procedure.

THE NINE BASIC STEPS OF AIR-PHOTO INTERPRETATION

Procedure is the heart of a technique. In a research method as inclusive as air-photo-interpretation, the geographer must proceed in a more or less standardized manner to insure completeness of photographic analyses. Thus, nine basic steps are suggested:

1) Study of available source materials. Air-photo-interpretation is another technique, not one that supercedes all others. Interpretation is not done of areas unknown to the interpreter excepting in emergencies. The properly used photo is a tool by means of which knowledge of an area or topic is advanced beyond existing information. Conversely, it is generally inefficient use of time to spend hours determining the presence of a particular kind of industry or species of tree when insurance atlases, telephone books, and Federal or State forest-inventory maps already disclose the information.

2) Plotting, indexing, and filing of cover. The photos must be arranged so that they are readily available, otherwise they are likely to be unused. A simple procedural step is to plot on a map, generally of much smaller scale than the photos, the outlines of the area covered by each photo and its number. Usually the most usable filing system is by the numbers of the photos as well.

3) Determination of photo scale and possibly of Linear Ratio. Often the scale of air-photo cover is known or it is shown on the index sheets. When not, the scale may be determined from the ratio of the camera focal-length to the flight elevation, data often shown in the marginal notations on the pictures. Otherwise, scale may be determined by the ratio of measured distances on the photos to distances determined from other source material or personal observation.

In areas of moderate to high relief, an interpreter may find that the scale of a single air-photo varies because of the elevational changes. For example, a variation of 500 feet elevation in an aiea covered by the usual Production and Marketing Administration photography of the United States will cause scale variations of about $3\frac{1}{2}$ per cent. The Linear Ratio may be computed to show the relationship between the average scale on the photo and the scales at different elevations. Or, the scales at the different elevations may be computed and used directly.

4) Plotting orientation points on the photographs. It is usually useful to mark with grease pencil on the coverage the names and locations of features which are orientation points for office or field work. These may be streams, hills, roads, section corners or like items and which have utility for location in both the office and the field.

5) *Mosaicing of coverage for general study.* The photographs should be overlapped in the manner in which they were taken. Geographers generally are searching for regional patterns; by general-viewing of the whole mosaic with the naked eye, or perhaps a low-power reading lens, the regional patterns are most likely to be apparent. During stereoscopic study, however, attention is likely to be focused on a very small area at any one time, and the general pattern is likely to be overlooked. It is important to precede detailed study of photos with the general examination because it is natuıal to look at the fine points, and because air-photos are usually on a scale so large as to include only a small area on each print. Generalization usually requires a conscious effort, and is advisable immediately preceding and following stereoscopic study.

6) *Computation of the Appearance Ratio.* This ratio, the ApR, is a general expression of the apparent height of objects in stereovision to the way they ought to look through the stereoscope. In general, interpreters usually see heights exaggerated while using a portable stereoscope and photos with the usual 60 per cent overlap along the line of flight. The ApR is designed to prevent misinterpretations from this exaggeration; an ApR of 2.6, for example, indicating that a hill 100 feet high appears to be 260 feet high. To date the ApR has yielded helpful and accurate results for both trainees and accomplished interpreters using the Department of Agriculture photography of the United States. However, unfavorable results have been obtained by using the Appearance Ratio, as given below, with military coverage or large-scale pictures flown for private organizations.

The Appearance Ratio is computed from four measurements:

$$\frac{\text{Picture Edge Distance}}{\text{Interpupillary Distance}} \times \frac{\text{Camera Focal-length}}{\text{Stereoscope Focal-length}}.$$

The picture edge distance is measured along the line of flight between the visible edges of two photos (to be viewed stereoscopically) when they are mosaiced. The interpupillary distance is the spacing between the centers of the eyes; it may be determined by measuring between the centers of the eyes; it may be determined by measuring between corresponding edges of the irises while each eye is looking straight ahead. The camera focal-length is often given in the marginal data, or may be determined from the agency which possesses or took the air photos. The stereosopic focal-length is the distance between the lenses of the instrument and the point on a card near the base of the legs at which an object (more than 50 feet away) is most clearly focused.

With a stereoscopic pair of the usual Production and Marketing Administration photos of the United States, an ordinary computation for the Appearance Ratio might be:

$$\frac{.208'}{.212'} \times \frac{.687'}{.350'} = 1.82.$$

This figure means that a hill 100 feet high appears to be 182 feet high for the specific interpreter looking through his own stereoscope at the particular two pictures.

7) *Pre-field stereoscopic study.* Close study in third dimension of overlapping vertical air-photos requires much mental discipline to insure good results.

Stereovision must be preceded by the proper grounding so that to the extent possible an interpreter knows where to look for what and what he is looking at. Also, only one or two types of thing should be interpreted at any one time, similar to the usual topical geographer's approach in a research project. Snap judgments must be prevented by a great deal of comparison and an even greater amount of measurement. Shadows must be traced to the originating features (shadows need not be falling toward the interpreter as is often stated) and, above all, complete use should be made of source materials (documentary, cartographic, statistical, and photographic) on the area photographed.

8) Field work with the stereoscope. Wherever possible, geographical air-photo-interpretation should be based upon observation in the area photographed. Field work affords the opportunity for the familiar ground view of elements as well as of collecting additional source materials. Even more significant is the stereovision done in the field while studying "problem" spots or analyzing a topic. Field stereovision usually is the stage of recognition of the greatest number of observable distinguishing characteristics for inclusion in an interpretational key.

9) Post-field stereoscopic study. This step is one of summarization. While studying stereoscopically the items being analyzed, a complete review should be made of all distinguishing characteristics determined from source materials, previous stereoscopic study, and field observation. The systematic listing of all of these characteristics is the final interpretational key.

After this last step in most geographic research the analyst becomes a specialist in content rather than technique. That is as it should be. With identifications made, relationships established, and types of distributional patterns classified, the next step is the explanation of the significant distributional patterns.

The Future of the Technique

There is a most promising future for geographical air-photo interpretation. The speed and amount of development are dependent largely upon the availability of finances with which to obtain coverage and filing space in which to store it, as well as the extent of the interpreters' patience and source materials.

Regardless, or because of, world events two types of new photography will be becoming available for some time. 1) Additional coverage of areas now unmapped or poorly charted is likely to be taken. 2) Programs of rephotographing areas of changing agriculture or of strategic importance probably will be continued. Either of the new coverages offers bases for much additional research in all fields of geographic investigation. For example, there will be materials for new geographic inventories, large-scale research in historical geography, and identifications of urban and rural land uses.

However, the advantages of this new photography, and some of the existing cover, are likely to be realized tardily. Geographers and fellow scientists will have to work simultaneously on fresh topics with new photos and three old problems.

1) Inadequacy of physical equipment. Centers of photography, like the National Air Photo Library of Canada, are few. More are needed and, particularly, depositories or centers of information about photography of all of the world. At the same time, less costly photographic reproduction, particularly in documentary publication, would be a great improvement for both research and training.

2) Incomplete research in the technique. Much analysis remains to be done on the relative utility of variously-scaled and -dated photography of the same area. Topical and regional keys are scarce. Standardization and minimization of interpretational terms is in order. In addition, few bibliographies are available on topical and regional source materials for air-photo-interpretation.

3) *Insufficient instruction in the technique.* A young field needs much new blood to grow. Potential interpreters require the opportunity for formal preliminary training in technique courses, balanced between the interpretation of both physical and cultural features. Paralleling the course requirements are those of instructional aids, including texts with balanced physical and cultural treatments, teaching materials (such as enlarged photos and specially designed stereograms), and instructional procedures.

It is on this third problem that attention needs to be concentrated. The development of efficient procedures in the instructional phases of air-photo-interpretation will result in improved physical equipment and research techniques. Thereby will geographic research itself become more fruitful.

THE USE OF AERIAL PHOTOGRAPHS IN THE GEOGRAPHIC ANALYSIS OF RURAL SETTLEMENTS

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THE identification and mapping of both cultural and natural features constitute first steps in the geographic analysis of an area. Heretofore, this inventory stage has demanded long and strenuous hours in the field. With the increasing use of aerial photographs, geographers are now able to accomplish this phase of their work more rapidly and with a higher degree of accuracy.

Aerial photographs are particularly helpful in the study of settlement geography, that aspect of geography which deals, functionally, with the character and arrangement of the works of man. Photographs facilitate the study of these phenomena in at least three distinct ways: (1) they provide information concerning the character and areal distribution of the contemporary elements and types of settlement; (2) they reveal the physical conditions involved in the process of settlement in detail and in accurate areal patterns, thus emphasizing the spatial relations of the settlement features and their distribution to the physical environment; and (3) they indicate the interrelations between settlement features and their surrounding area (fields, hinterland, work area). Examples included within this paper illustrate each of these three ways in which aerial photographs aid the settlement geographer. These examples have been drawn from studies in rural settlement geography, recently undertaken in connection with a contract with the Geography Branch of the Office of Naval Research.[1]

The Focus of Rural Settlement Geography

The study of rural settlements is a product of very recent times in American geography. Such studies are distinct from urban settlement studies because they are concerned with the cultural features that man has built in order to wrest his living from the soil. Unlike urban settlements, rural settlements are generally dispersed over the countryside, although in many parts of the world

[1] Project N7 onr 45-005, Northwestern University, under the direction of Clyde F. Kohn and William E. Powers.